New Jersey Low-Level Radioactive Waste Disposal Plan

2000 Update

September 7, 2000

New Jersey Low-Level Radioactive Waste Disposal Facility Siting Board

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EXECUTIVE SUMMARY

In 1987, the New Jersey Low-Level Radioactive Waste Disposal Facility Siting Board (Siting Board) was established and designated to find a site for a low-level radioactive waste (LLRW) disposal facility. The Siting Board reviewed data on areas of the State that could support a facility, but shifted to a voluntary process in 1995. For three years, the Siting Board worked with communities considering volunteering to host a facility. In 1998, because of the availability of out-of-state disposal facilities and the continued volume reduction of LLRW for disposal, the Siting Board voted to suspend the siting process.

Data in this report shows the decrease over the last ten years in volume and activity sent to the available out-of-state disposal facilities. This is due to waste minimization techniques that limit the waste generated and to waste processing techniques that decrease the volume of waste for disposal. Decreases in waste to the available full service LLRW facility are also due to the availability of facilities handling limited waste streams. However, volume and activity of LLRW for disposal is projected to increase within the next twenty years due to the scheduled decommissioning of the State's nuclear power plants.

The Siting Board has worked with the Northeast Compact and representatives from the states of Connecticut, New Jersey and South Carolina to secure long term (approximately 50 year) access to the existing LLRW facility in Barnwell, South Carolina for disposal of LLRW projected for routine and decommissioning operations. This effort was concluded on July 1, 2000 when South Carolina joined the Northeast Compact (now called the Atlantic Compact) and agreed to be the host state for LLRW disposal of the Compact. Low radioactivity concentration waste continues to be disposed at the Envirocare facility in Clive, Utah.

1.0 INTRODUCTION

1.1 Background of Siting Process

The federal Low-Level Radioactive Waste Policy Act of 1980 and Amendments Act of 1985 require that each state provide for the disposal of low-level radioactive waste generated within its borders. The legislation encouraged states to form regional compacts, which could then limit use of their disposal facilities to their member states. It also gave states with existing disposal facilities the authority to restrict use of their facilities.

To help meet this mandate, the New Jersey Legislature passed the Regional Low-Level Radioactive Waste Disposal Facility Siting Act in 1987. This Act established the New Jersey Low-Level Radioactive Waste Disposal Facility Siting Board and the New Jersey Radioactive Waste Advisory Committee.

In the early 1980's, eleven states in the Northeast region established a working group to consider the development of a Northeast Compact. Working with the Coalition of Northeastern Governors, this group drafted the *Northeast Compact Act*. In 1983, the *Act* was sent to the governors of the eleven states. The *Act* was approved by the legislatures in four states: New Jersey, Connecticut, Delaware and Maryland. Delaware and Maryland subsequently withdrew from the Northeast Compact to join the Appalachian Compact.

In December 1987, the Northeast Compact designated New Jersey and Connecticut to each host disposal facilities.

After several years of effort to locate a site in New Jersey using deterministic criteria, the Board in 1992 shifted to a voluntary siting process, wherein interested individuals, organizations and communities had the opportunity to learn about the process and offer, without commitment, potential sites for detailed study. In February 1995, the Board adopted *New Jersey's Voluntary Plan for Siting a Low-Level Radioactive Waste Disposal Facility,* which describes this voluntary siting approach.

In February 1998, the Board voted to suspend the siting process, citing continued though unpredictable availability of out-of-state disposal combined with a dramatic reduction in the volume of waste generated. In addition, the Board completed a Disposal Option Report to the Governor of New Jersey in June 1999 and distributed it to interested parties in New Jersey and the country. One of the findings of this report conclude that "currently there are disposal facilities accessible to New Jersey generators of low-level radioactive waste and there appears to be several national developments in the waste management dilemma that are being pursued which may resolve the issue for New Jersey."

1.2 Disposal Plan History

Among the provisions of the Regional Low-Level Radioactive Waste Disposal Facility Siting Act is the requirement that the Siting Board develop and adopt a *Low-Level Radioactive Waste Disposal Plan,* and update it every three years. An update was not prepared for the period from 1990-1993, however, because the Siting Board was focused on changing from a "top-down" to a Voluntary Siting Process. As a result, the *1996 Update* provided information for the six-year period 1990-1996, with disposal data from the 1989-1993 period. Disposal data for the years 1994-1998 is now available in this document.

While the *Disposal Plan 2000 Update* provides information that can be used for several purposes, its primary function is to provide data to the Siting Board, the Advisory Committee and the general public that will help them make informed decisions about the safe disposal of New Jersey's low-level radioactive waste.

Since the first *Disposal Plan* was adopted and distributed in 1990, four significant changes have affected the disposal of low-level radioactive waste generated in New Jersey.

In 1990, there were three operating disposal facilities in the United States, located in Barnwell, South Carolina; Richland, Washington; and Beatty, Nevada. By July 1994, the facility in Nevada had closed and the other two had restricted access to exclude generators from New Jersey and most other states. Consequently, low-level radioactive waste generated in New Jersey between July 1, 1994 and June 30, 1995 was stored, on an interim basis, where it was produced, at approximately 100 locations. In July 1995, the facility at Barnwell was re-opened to generators for an indeterminate period of up to ten years.

The report focuses on the LLRW that has been disposed of and is projected to be disposed of at the Chem-Nuclear facility in Barnwell, South Carolina. Use of the Envirocare facility in Clive, Utah for lower concentrations of LLRW has increased in recent years. Disposal data and projection data for this facility will not be discussed in detail in this report because the data is sketchy at best and future availability of this facility appears excellent.

The second significant development was the decision by the Siting Board in February 1995 to undertake a voluntary approach to find a suitable location for a disposal facility for the low-level radioactive waste generated in New Jersey. Previously, the Siting Board had planned to identify a number of potential sites through a statewide screening process, and only then engage in active discussions with area residents. Under the Voluntary Siting Process, the Siting Board would have only begun to examine a potential site after one is suggested by members of the community. This approach is described in *New Jersey's Voluntary Plan for Siting a Low-Level Radioactive Waste Disposal Facility,* dated March 1995.

The third significant development was the decision of the Siting Board in February 1998 to suspend the siting process. A number of towns had serious discussions with the Siting Board regarding their interest in hosting a disposal facility, but New Jersey still had access to out-of-state disposal. It was determined that a facility in New Jersey was not needed at this time.

The fourth significant development was the September 1999 proposal of the Northeast Compact for South Carolina to join the Compact which would meet the South Carolina's desire to limit access to their disposal facility and reserve capacity at that site for South Carolina generators. After successful negotiations, South Carolina joined the Northeast Compact and provided long-term (approximately 50 year) arrangement for access to the Barnwell, South Carolina disposal facility for New Jersey and Connecticut generators.

1.3 Radioactivity

Radionuclides are nuclides[1] that are unstable, meaning they have too much energy. In order to shed their excess energy, radionuclides spontaneously undergo radioactive decay. This is the process by which the nucleus of an atom transforms to a low energy state by emitting radiation such as alpha, beta or gamma. As radionuclides decay, they are transformed from one nuclide to another. The resulting nuclide (called "daughter" or "progeny" or "decay product") may or may not be radioactive. The sequences of transformations (called "decay series" or "decay chain"), as well as the types and strengths of emissions are specific to each radionuclide and well known to scientists. Decay chains end when a radionuclide transforms into a stable (non-radioactive) nuclide.

The half-life is the time it takes for half the atoms of a radionuclide to be transformed through radioactive decay. Each radionuclide has its own specific half-life, which range from fractions of seconds to billions of years. Radionuclides with short half-lives release their energy through decay faster than those with long half-lives. Consequently, waste containing radionuclides with long half-lives remains radioactive for a longer period of time.

It should be noted that a longer half-life does not necessarily imply a greater health hazard. Many factors besides half-life influence the degree to which a radioactive waste poses a health hazard. These include concentration of radioactivity, types and strengths of emissions and waste characteristics.

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[1] While all atoms of the same element contain the same number of protons, variants of elements called isotopes differ in their number of neutrons. An element may have many isotopes, each of which has the same number of protons and electrons, but a different number of neutrons. Nuclide is a broader term that refers to any isotope of any element.

1.4 Radioactive Waste

Radioactive waste is generated in several ways:

- Material is considered radioactive after it comes in contact with, and is contaminated by, radionuclides. Examples of radioactive waste resulting from contamination include laboratory waste such as used test tubes and gloves that have come into contact with radioactive isotopes, and filter resins from nuclear power plants. The non-radioactive elements within the contaminated material do not become radioactive; rather, atoms that are radioactive adhere to the surfaces or become mixed within the original material. The majority of the volume of radioactive waste is generated by contamination.
- Radioactive waste is also generated by incidental activation of stable (non-radioactive) materials. Activation is the process by which stable nuclides absorb energy and become radionuclides. For instance, certain non-radioactive elements of metal alloys in nuclear power plants, through activation, become radionuclides such as iron-55, cobalt-60, and nickel-63. Activated hardware comprises the majority of the radioactivity of low-level radioactive waste. The radionuclides remain mostly bound within the hardware and are not readily released into the environment.
- A third means by which radioactive waste is generated is by discarding sealed sources that are no longer useful. Such material is typically contained within a measuring device or gauge. For instance, the tritium (hydrogen-3) source in a gas chromatograph could be discarded after it is no longer useful.

Radioactive waste is measured in terms of both volume and radioactivity. Volume, expressed in cubic feet , is the physical space occupied by the waste and its container. The strength or radioactivity is the rate at which radiation is emitted; this is expressed in curies. The radioactivity (or activity) of a waste is equal to the sum of the radioactivities of all the radionuclides present in that waste. Because different waste streams have very different radioactivity concentrations, a small volume of one waste may contain much more radioactivity than a large volume of another waste.

1.5 Waste Classifications

The term "low-level radioactive waste" is commonly used in reference to any waste with a low concentration of radioactivity. However, the more specific legal definition[2] is intended throughout this document. Low-level radioactive waste (LLRW) is defined as radioactive waste subject to regulation by the U.S. Nuclear Regulatory Commission (NRC) that is not high-level radioactive waste, spent fuel, uranium or thorium mill tailings, or nuclear weapons byproducts. This definition excludes material not subject to the Atomic Energy Act of 1954 and therefore regulated by the states and not the NRC, namely Naturally-occurring or Accelerator-produced Radioactive Material (NARM). Because the federal Low-Level Waste Policy Act and Amendments Act pertain only to LLRW, it is not the responsibility of the Siting Board to provide disposal capacity for State-regulated NARM or High-Level Radioactive Waste.

The NRC classifies commercial LLRW as Class A, B or C based on the concentrations of specific radionuclides listed in Tables 1 and 2 of 10 CFR 61.55, with Class A waste having the

[2] 10CFR61.2 (Title 10 Code of Federal Regulations Chapter 61.2)

lowest concentration and Class C having the highest concentration. A waste container need have only one radionuclide above a level specified in Table 1 or 2 to be classified accordingly. Class B and C wastes must be stable, meaning the waste form or container must maintain gross physical properties and identity for at least 300 years. Physical stability of both the waste and the disposal site provides protection to the general population by minimizing access of water to the waste, thus minimizing migration of radionuclides from the waste. In order to protect the inadvertent intruder,[3] Class C waste must also be placed deeper or under some type of intruder barrier such as concrete.

A mixed waste is a radioactive waste that also contains chemical constituents classified as hazardous under US Environmental Protection Agency (EPA) or New Jersey Department of Environmental Protection (DEP) regulations. Examples of mixed wastes include organic liquids such as some scintillation liquids as well as wastes containing lead and chromium.

1.6 Generator Categories

LLRW is generated by a variety of activities, including electrical power generation by nuclear power plants, medical/pharmacological research and development, and clinical and diagnostic medical practices. For the purposes of this *Disposal Plan 2000 Update,* generators are grouped into the categories: academic, government, industrial, medical, and utility. In some cases, the placement of a generator into a category is somewhat arbitrary in that a generator may fit in more than one category. For instance, a university hospital could have been designated as "medical" instead of "academic." Nonetheless, the use of generator categories helps describe LLRW generation in New Jersey. Section 2.0 lists generators by category that disposed of this waste at least once from 1984-1998.

1.7 Waste Types

The diverse types of LLRW were grouped into categories in the 1994-1998 generator surveys. The radiological characteristics of the waste depend on its origin.

- Dry active waste is contaminated trash. It includes miscellaneous items such as paper, plastic and discarded clothing.
- Biological waste is generated at hospitals and research institutions and may consist of laboratory animal carcasses, animal tissues, bedding, excreta and labeled culture media.
- Ion exchange resins, liquid filter media and evaporator concentrates originate from liquid processing at nuclear power plants.
- Liquid waste may be solidified with cement before disposal.
- Activated hardware is primarily material that has been exposed to neutron irradiation in a nuclear reactor.
- Hardware/gauges is equipment and devices that are contaminated with or contain radioactive material.

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[3] Inadvertent Intruder is defined by 10 CFR 61.2 as a person occupying the disposal site after closure and engaging in normal activities in which the person might unknowingly be exposed to radiation from the waste.

- Small sealed sources come from calibration devices, gauges and other instruments. High activity sealed sources, used in medical therapy applications as well as radiography devices, can often be returned to the manufacturer for reuse or recycling.

1.8 Waste Forms and Containers

Several minimum requirements regarding waste forms and containers are specified by the NRC.[4] Liquid waste must be solidified or packaged in material sufficient to absorb twice the volume of the liquid. Neither liquid nor solid waste is allowed to contain more than 1% by volume of free-standing and non-corrosive liquid. All waste, by virtue of its form or disposal container, must have structural stability. This general stability is different from the more stringent stability requirements for Classes B and C wastes; it simply means that the waste will maintain its physical dimensions and form under the expected disposal conditions. Various containers are used to store and dispose of low-level radioactive waste, such as metal drums, gas cylinders and high-integrity containers (HICs). Cardboard or fiberboard boxes are not acceptable disposal containers.

1.9 Generator Surveys

Detailed surveys of LLRW generators were conducted for the years 1994-1998. Information from the 1988 survey may be found in the *Disposal Plan* published by the Siting Board in 1990. Survey data for the years 1989-1993 can be found in the *1996 Update* of the Disposal Plan. This *2000 Update* focuses on survey data from disposal in 1994-1998. Data were obtained from generators regarding land disposal, treatment, waste in storage, waste held for decay and alternative release mechanisms such as sewer disposal allowed by the NRC. Information such as waste stream volumes, containers, individual radionuclide activities and waste form was also collected. A computer database was used to store and access the data.

Federal data for waste disposed in commercial LLRW disposal facilities are contained in the Manifest Information Management System (MIMS) maintained by the U.S. Department of Energy at the Idaho National Engineering and Environmental Laboratory. These data were taken from manifests that accompany waste shipments to disposal sites. The manifest describes in detail the contents of an individual shipment, including the radioactivity of each nuclide. Radionuclides present in undetectable quantities tend to be overestimated because the lowest level of detection for the particular radionuclide is recorded on the manifest even though that level is known to be greater than what is actually in the waste. Data from the MIMS were used to determine disposal surcharges as well as New Jersey State generator fee assessments. This document primarily uses MIMS data, however data on LLRW disposal obtained from the generator surveys was used for details of waste categories and radionuclide content.

2.0 Current LLRW Generators in New Jersey

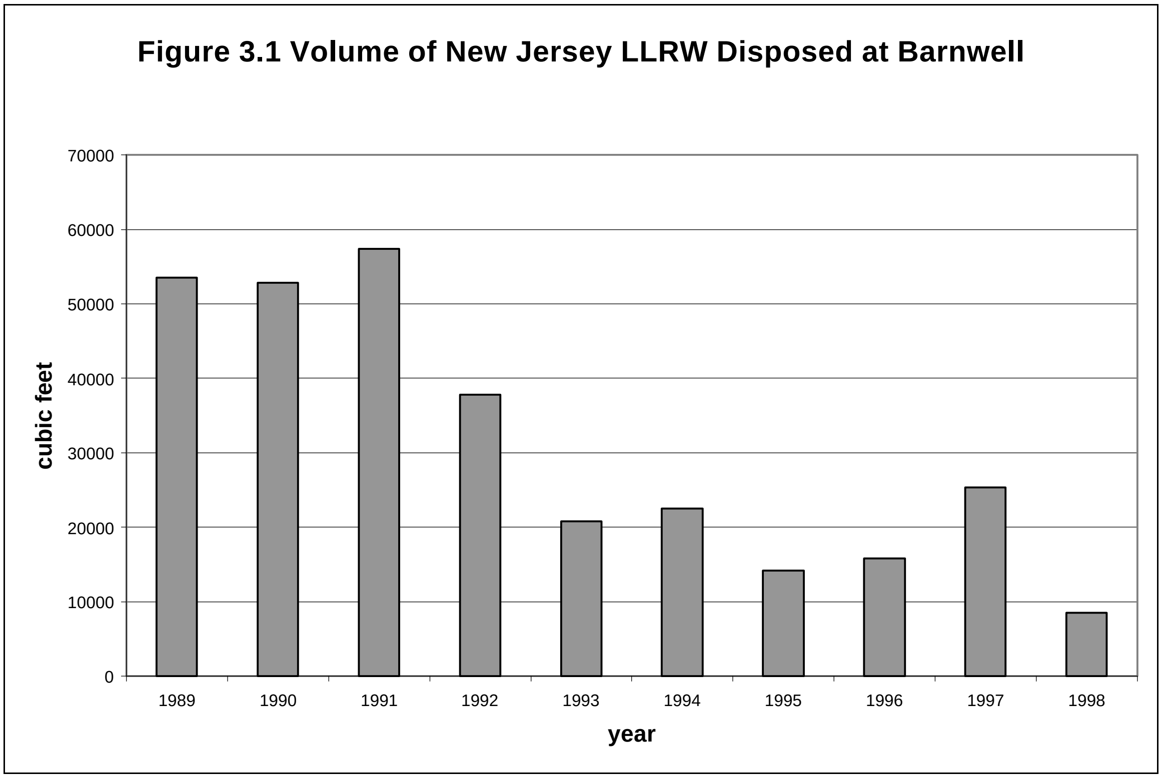
The table in Appendix A lists the NRC licensed facilities and others that disposed of LLRW at least once in the years 1994 through 1998. The table separates the facilities according to the facility categories described in Section 1.6.

[4] 10CFR61.56

3.0 Current LLRW Generated in New Jersey

3.1 Volume and Activity History

Figure 3.1 shows that there is a significant downward trend in the volume of waste sent to the Barnwell disposal facility, especially if one were to discount the 6828 cubic feet in 1996 and 20478 cubic feet in 1997 due to the scrap steam generators from the Salem I nuclear facility.



Both in the five year period 1989-1993, see Figure 3.2, and the five year period 1994-1998, see Figure 3.3, most of the volume of LLRW disposed was Class A. The Class B volume ranged from five to seven percent; the Class C volume was approximately one percent.

Figure 3.2 Volume of New Jersey LLRW Disposed at Barnwell by Waste Class, 1989 - 1993 totals

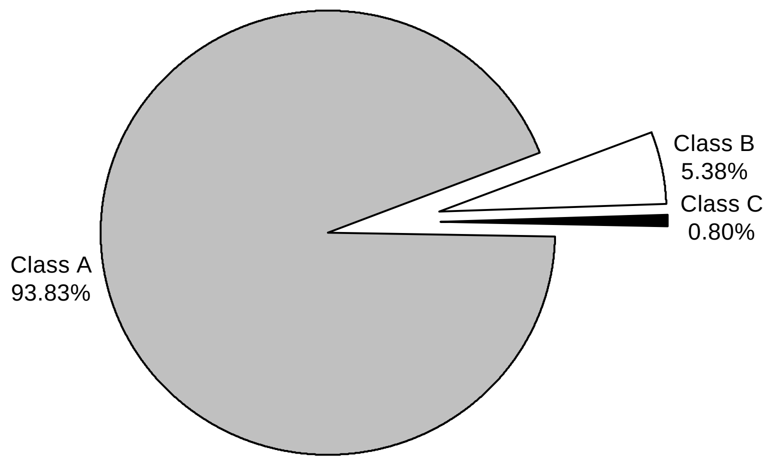
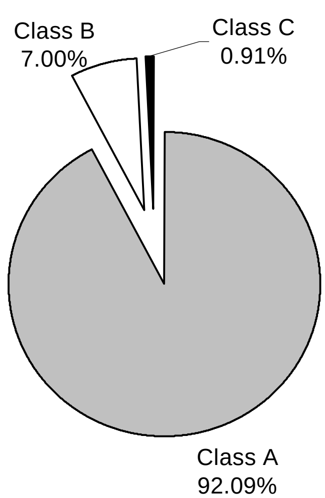


Figure 3.3 Volume of New Jersey LLRW Disposed at Barnwell by Waste Class, 1994-1998 totals



As seen in Figure 3.4, the decrease in activity disposed has been significant since the 317,833 curies disposed in 1989. In 1989, GPU Nuclear's Oyster Creek Nuclear Generating Station disposed of 232,000 curies of Class C activated hardware collected since the station first began operating in 1969. Also in 1989, Process Technology disposed of a single 26,100 curie Class B Cobalt-60 sealed source.

Figure 3.4 Activity of New Jersey LLRW Disposed at Barnwell

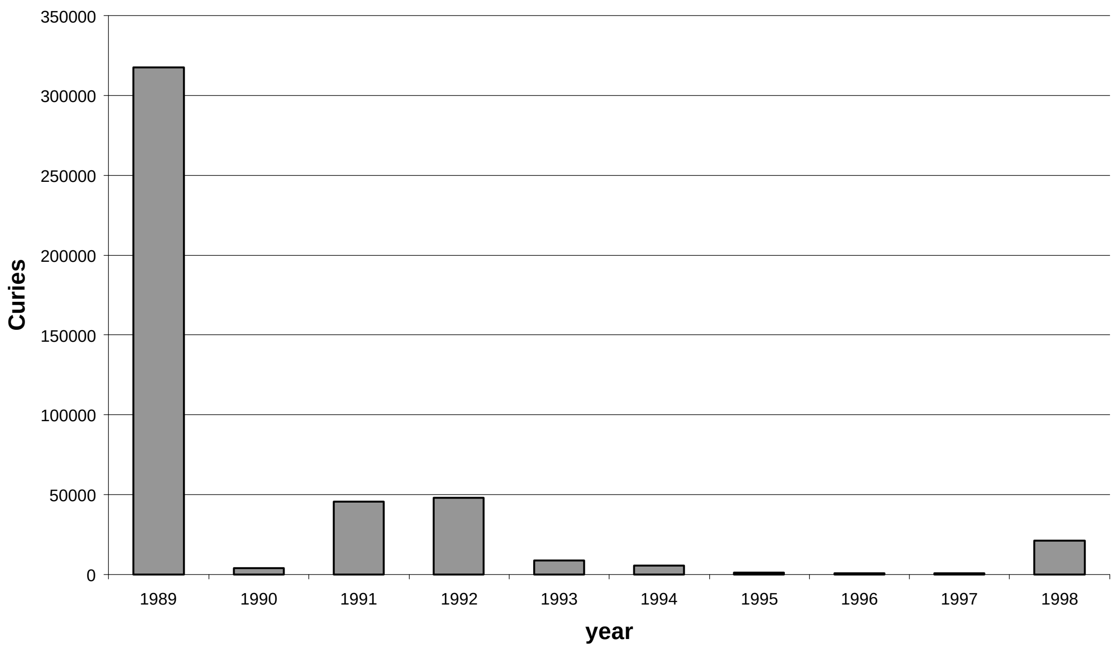


Figure 3.5 shows that the majority of activity was in Class C waste in the years 1989-1993. Figure 3.6 shows that the majority of activity was in Class B waste in the years 1994-1998.

Figure 3.5 Activity of New Jersey LLRW Disposed at Barnwell by Waste Class, 1989-1993 totals

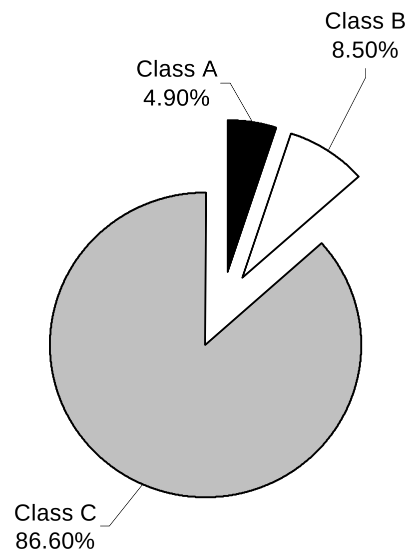
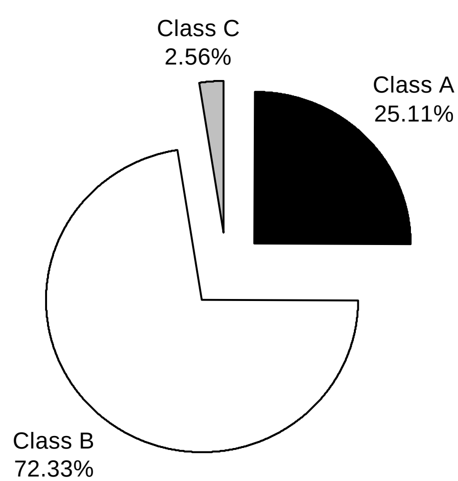


Figure 3.6 Activity of New Jersey LLRW Disposed at Barnwell by Waste Class, 1994-1998 totals



Figures 3.7 and 3.8 show that the vast majority of volume disposed at the Barnwell facility has been from utilities. Industries have also contributed a significant percentage.

Figure 3.7 Volume of New Jersey LLRW Disposed at Barnwell by Generator Category, 1989-1993 totals

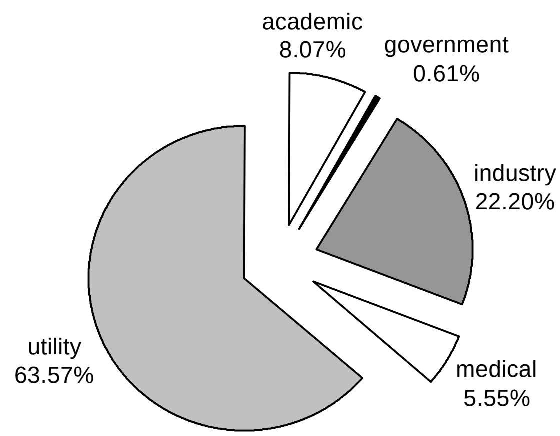
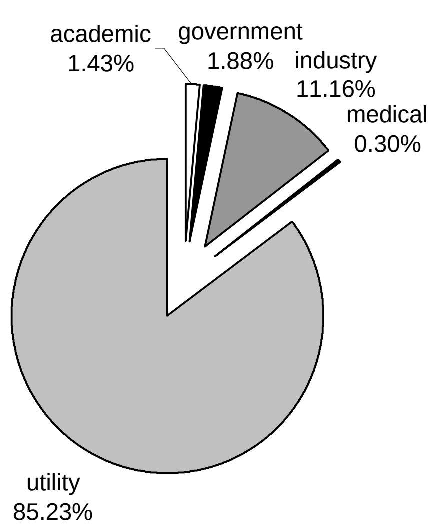


Figure 3.8 Volume of LLRW Disposed at Barnwell by Generator Category, 1994-1998 totals



Figures 3.9 and 3.10 show that the majority of activity in curies disposed at the Barnwell facility has been from utilities. The government has also added a significant percentage of this activity in the years 1994-1998.

Figure 3.9 Activity of New Jersey LLRW Disposed at Barnwell by Generator Category, 1989-1993 totals

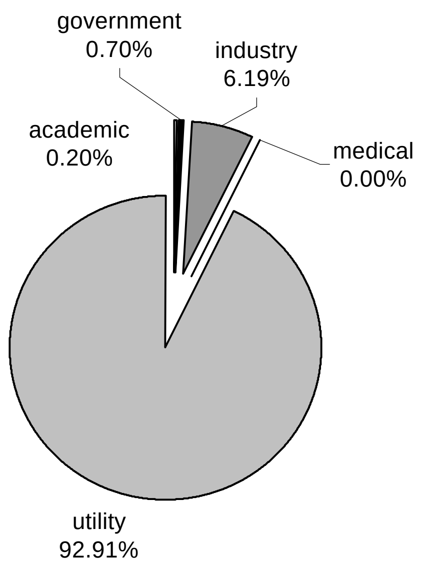
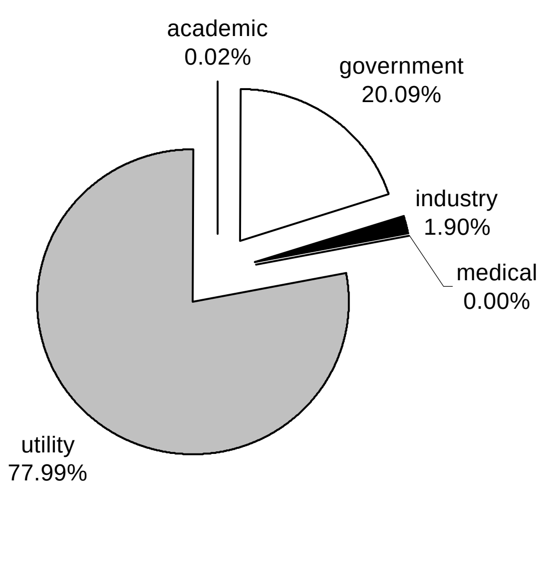


Figure 3.10 Activity of New Jersey LLRW Disposed at Barnwell by Generator Category, 1994-1998 totals



Figures 3.11 and 3.12 show that the greatest disposal volume is from dry active waste. Ion exchange resins are regularly a significant percentage of the volume. The large percentage of hardware in the years 1994-1998 is due to the disposal of Salem I Nuclear Generating Station's steam generator, see Section 3.1.

Figure 3.11 Volume of New Jersey LLRW Disposed at Barnwell by Waste Type, 1989-1993 totals

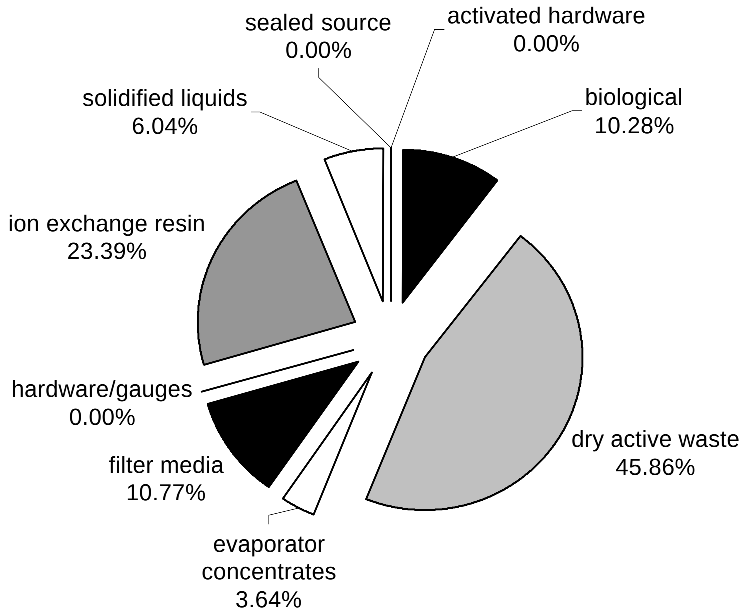


Figure 3.12 Volume of New Jersey LLRW Disposed at Barnwell by Waste Type, 1994-1998 totals

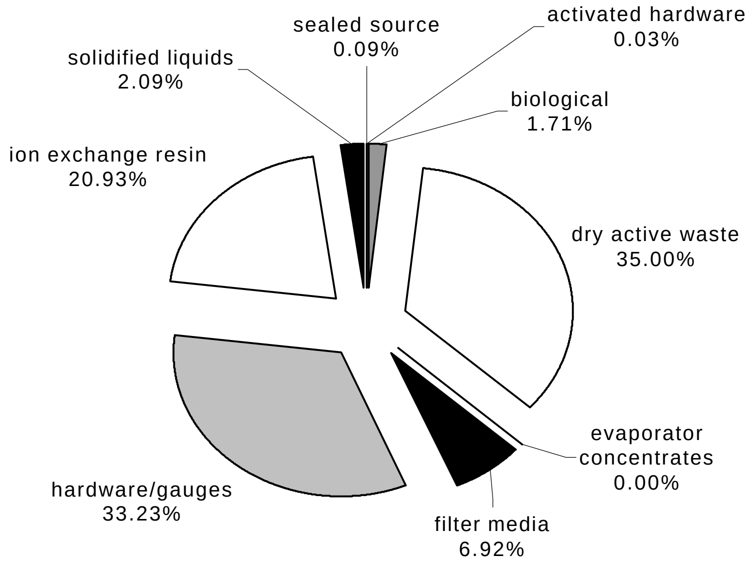


Figure 3.13 shows that the greatest activity in the years 1989-1993 was due to activated hardware, which is mostly Class C, see Figure 3.5.

Figure 3.13 Activity of New Jersey LLRW Disposed at Barnwell by Waste Type, 1989-1993 totals

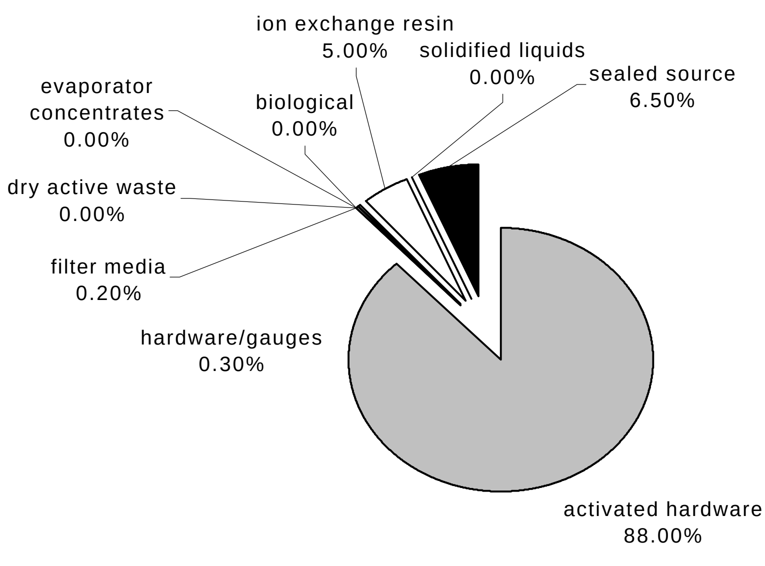
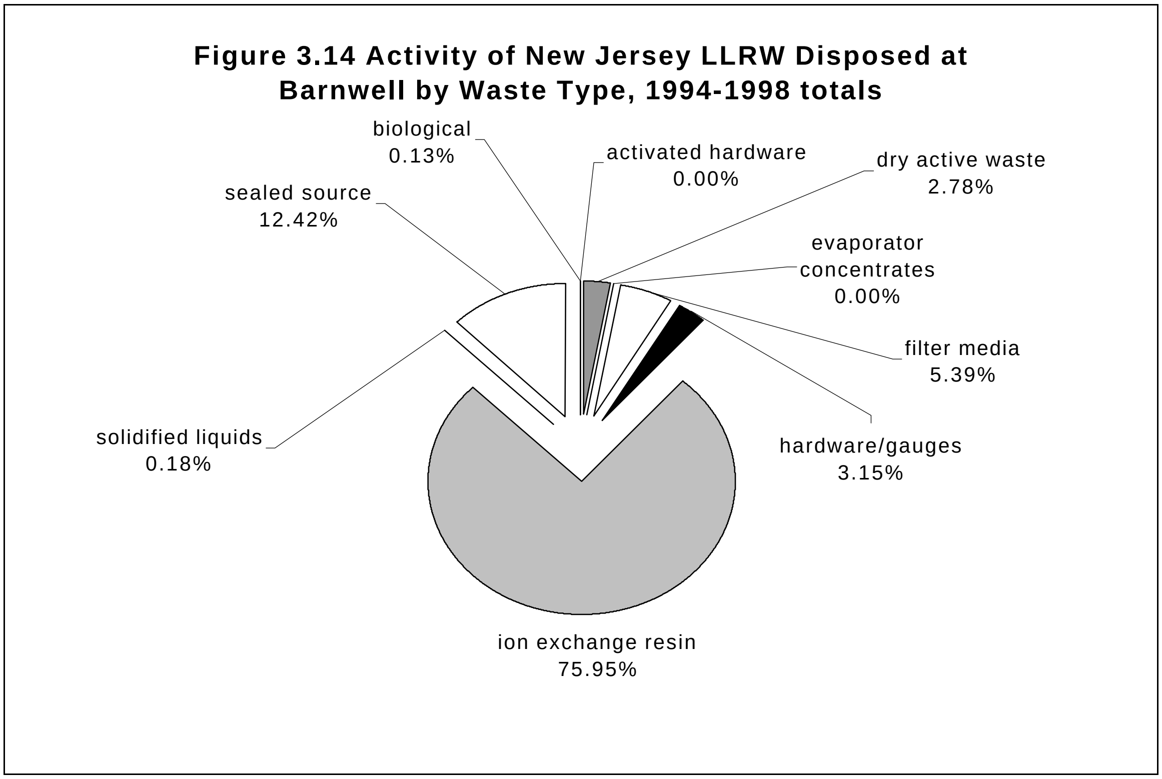


Figure 3.14 shows that the greatest activity in the years 1994-1998 was due to ion exchange resins, which is mostly Class B, see Figure 3.6.



3.2 Isotope History

The table in Appendix B shows the annual average radionuclide activities in LLRW disposal at Barnwell for the years 1994-1998. It also indicates the half-life of each of these radionuclides and calculates the activity for this average after 100 years of decay.

4.0 LLRW Disposal Projections

4.1 Utility Decommissioning

All facilities that use radioactive materials, including electrical generating, industrial, manufacturing, and research and development (R&D) facilities, are expected to be decommissioned at the end of their useful lives using a procedure consistent with protection of the public health and safety. The resulting decontamination and decommissioning (D&D) activities at these nuclear facilities will generate LLRW. The majority of the waste generated by D&D in New Jersey will come from the four nuclear power plants.

Decommissioning is a generic term that includes whatever actions are required to accomplish termination of a power plant's nuclear license and the release of the property for unrestricted use. These actions can range from radiation surveys that show that the residual radioactivity has decayed to acceptable levels, to dismantlement and removal of radioactive components and structures. The timing of dismantlement activities may be either immediate or deferred.

Several studies[5] have been performed on the decommissioning of commercial nuclear power plants. The volume of radioactive waste and practices associated with decommissioning nuclear reactors are described in these documents. Two basic approaches to decommissioning are considered:

- **Immediate Dismantlement** - Radioactive materials are removed and the plant is disassembled and decontaminated during the four-year period following final cessation of power production operations and a two-year planning and preparation period. Upon completion and with regulatory approval, the property is released for unrestricted use.
- **Safe Storage with Deferred Dismantlement** - Radioactive materials and contaminated areas are secured, and structures and equipment are maintained as necessary to ensure the protection of the public from any residual radioactivity. Public access is restricted during this period of Safe Storage, which could last more than 50 years. Dismantlement is deferred until the radioactivity within the plant has decayed to significantly lower levels, a disposal facility is available, and economics allow for dismantlement to proceed. Upon completion of dismantlement and with regulatory approval, the property is released for unrestricted use.

At least two variations on the D&D approaches exist. While this *Disposal Plan 2000 Update* does not attempt to quantify the waste produced from the following D&D approaches, they represent viable alternatives that may fit existing economics:

- **Piecemeal Dismantlement** - Selected areas of the plant are decontaminated and dismantled, while other areas are kept in Safe Storage with Deferred Dismantlement. This approach represents a middle ground between the previous two options. Piecemeal Dismantlement was undertaken by Yankee Rowe in Massachusetts and Fort St. Vrain in Colorado in 1992-1993; their choice of D&D approaches was influenced by the availability of disposal for LLRW.
- **Selective Dismantlement with Restrictions** - Portions of the site are dismantled (e.g., the reactor and fuel components) and the license is terminated with restrictions on future use of the site. For example, much of the site could be reused for non-nuclear power production by installing a boiler, and reusing the turbine and generator.

A broad span of methods is possible under Safe Storage, ranging from:

- minimal removal, then fixation of remaining radioactivity followed by active maintenance and surveillance; to
- extensive decontamination, then passive protection of highly radioactive areas using temporary entombment.

Each method encompassed within Safe Storage requires some level of continuing care during the holding period, which may vary in length from a few years to more than 50 years.

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[5] Murphy, E.S., R.I. Smith, W. Kennedy. 1984. *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station,* Volumes 1-2 and Addendum. Pacific Northwest Laboratory. NUREG/CRO130.
Oak, H.D., G.M. Holter, W.E. Kennedy Jr., G.J. Konzek, 1980. *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station, Volumes 1-2.* Pacific Northwest Laboratory. NUREG/CR0672.

Projecting D&D waste volumes and activities involves several variables. Many factors influence the timing and the amount of LLRW generated, including:

- life extension plans of power reactors;
- decommissioning plans for multireactor sites;
- siting and operation of a geologic repository for high-level radioactive waste, including spent fuel rods;
- the method of decommissioning selected;
- decommissioning regulations;
- the recycling and reuse of components; and
- reuse of the site and/or structures.

All four nuclear power plants in New Jersey have been granted plant life extension permits to "recover" the time difference between the approval of the construction permit and the actual startup date of the plant. Table 4.1 presents the current plant life cycle schedules for the nuclear power plants, taken from the 1993 Annual Report of the New Jersey Department of Environmental Protection's Bureau of Nuclear Engineering, the most up-to-date data available.

Table 4.1 Nuclear Power Plant Life Cycle Schedules

Nuclear Power Reactor	Power Rating (Mwe)*	Full-Term Operating License Date	Commercial Operation Start Date	Full-Term Operating License Expiration Date
Oyster Creek	650	July 1991 **	December 1969	April 2009
Salem 1	1115	December 1976	June 1977	August 2016
Salem 2	1115	May 1981	October 1981	April 2020
Hope Creek	1067	July 1986	December 1986	July 2026

*Mwe = Mega Watt-Electric
**Provisional operating license granted August 1969

Operators of sites with multiple reactor units might opt to delay decommissioning of a reactor plant to coincide with the decommissioning of a second facility. For example, Salem 1, Salem 2 and Hope Creek are all at the same site and the decommissioning of the older units, Salem 1 and 2, might be delayed to coincide with the decommissioning of Hope Creek.

Another factor that may influence the timing of reactor plant decommissioning is the availability of off-site disposal or storage for Greater Than Class C waste and spent fuel. The U.S. Department of Energy estimates that the federal High-Level Waste (HLW) geologic repository will not be available before 2010.

Most of the waste generated from decommissioning nuclear power plants consists of contaminated concrete rubble and contaminated metal. The decommissioning of a reference PWR[6] and a reference BWR[7] include the following waste information.

[6] Murphy, E.S., R.I. Smith, W. Kennedy. 1984. *Technology, Safety and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station,* Volumes 1-2 and Addendum. Pacific Northwest Laboratory. NUREG/CRO 130. Table G4-2

[7] Oak, H.D., G.M. Holter, W.E. Kennedy Jr., G.J. Konzek, 1980. *Technology, Safety and Costs of Decommissioning a Reference Boiling Water Reactor Power Station, Volumes 1-2.* Pacific Northwest Laboratory. NUREG/CR0672. Table I 3-2.

There is considerable uncertainty regarding the actual decommissioning approach for the power reactor sites. Immediate Dismantlement, for financial planning purposes, is the most often assumed decommissioning approach. The approach chosen will affect the actual date for the receipt of decommissioning waste. Immediate Dismantlement would yield waste for disposal shortly after reactor shutdown or operating license expiration; Safe Storage could delay the generation of most D&D waste for more than 50 years.

The Immediate Dismantlement alternative results in the generation of waste with greater radioactivity. The waste generated during Deferred Dismantlement includes waste from preparations for Safe Storage, continuous maintenance, and from subsequent decommissioning. The total radioactivity of waste from Deferred Dismantlement should be much less than that from Immediate Dismantlement because of radioactive decay; the extent of the reduction depends on the number of years decommissioning is deferred.

Other items that might have an impact on decontamination and decommissioning waste are the regulatory framework, recycling or reuse activities, and other disposal alternatives. The nuclear plant D&D volume estimates are based on the volumes from decommissioned reactors under certain regulatory guidelines, and then scaling this volume to the size of the plant to be decommissioned. One factor that can significantly affect the volume of very low activity D&D waste will be the site decommissioning clean-up criteria established by the NRC and the State. Depending on how low the criteria for unrestricted access are set, significant volumes of site cleanup soil and rubble may need to be disposed of as low-level radioactive waste. Metallic components of the waste stream are currently being recycled. These metals are captured before disposal, remelted, and used to manufacture specific products such as radiation shielding. Programs are also underway to recycle this metal to manufacture the metal containers that are used for LLRW disposal. Nuclear plants expect to dispose 30.6% to 82.1% of its D&D volume as contaminated metallic components (Table 4.2), much of which may be recovered. The high cost of disposal will continue to drive recycling and reuse activities to reduce the LLRW volume from D&D.

Table 4.2 D&D Wastes from Reference Reactors

Radioactive Waste		PWR Volume %	BWR Volume %
Neutron Activated Materials	Metal	2.7	0.7
	Concrete	3.9	0.5
Contaminated Materials	Metal	30.6	82.1
	Concrete	59.3	8.8
Other Waste	e.g. DAW	3.5	7.9
	TOTAL	100.0	100.0

Even the concrete from the D&D waste could be recycled and used as the disposal vault and grouting fill. The technology for recycling uncontaminated or non-radioactive concrete exists and is routinely applied in New Jersey. Large volume, very low-level radioactivity waste may be disposed at the Envirocare facility in Clive, Utah.

Representatives of the two corporations that own New Jersey's nuclear power reactors have provided the Siting Board with volume and activity projections[8,9], both for normal and D&D operations. For all plants, the currently assumed approach to D&D is Immediate Dismantlement and minimal use of recycling or reuse programs for metal components is assumed. These estimates are broken down by waste class in Figure 4.2 and 4.3 respectively. Greater Than Class C waste will not be disposed of in a LLRW disposal facility.

4.2 Non-Utility Decommissioning

New Jersey has many facilities other than nuclear power plants that will eventually require D&D. Most of these are small and will not generate significant volumes of LLRW. Additionally, because the operating licenses for these types of facilities are routinely extended by the NRC, accurate decommissioning dates cannot be estimated based upon current license expiration dates. In addition, generator survey data has not yielded useable data.

4.3 Site Remediation and Envirocare Data

Due to New Jersey Superfund and private site remediation projects, it is estimated that the average volume of soil disposed at Envirocare will be 5000 cubic feet per year for the foreseeable future.   Most of the waste is Naturally Occurring Radioactive Material (NORM). This estimate is based on the assumption that sites will be cleaned to the unrestricted use standard.

Use of the Envirocare Utah facility is increasing. Recent increases in allowable concentrations have made this facility available for a greater percentage of Class A LLRW. Generators have used this option mainly because of the cost advantages compared to disposal at the Barnwell facility. Figure 4.1 shows the projected volume of waste that will be sent to this facility during the next 20 years.

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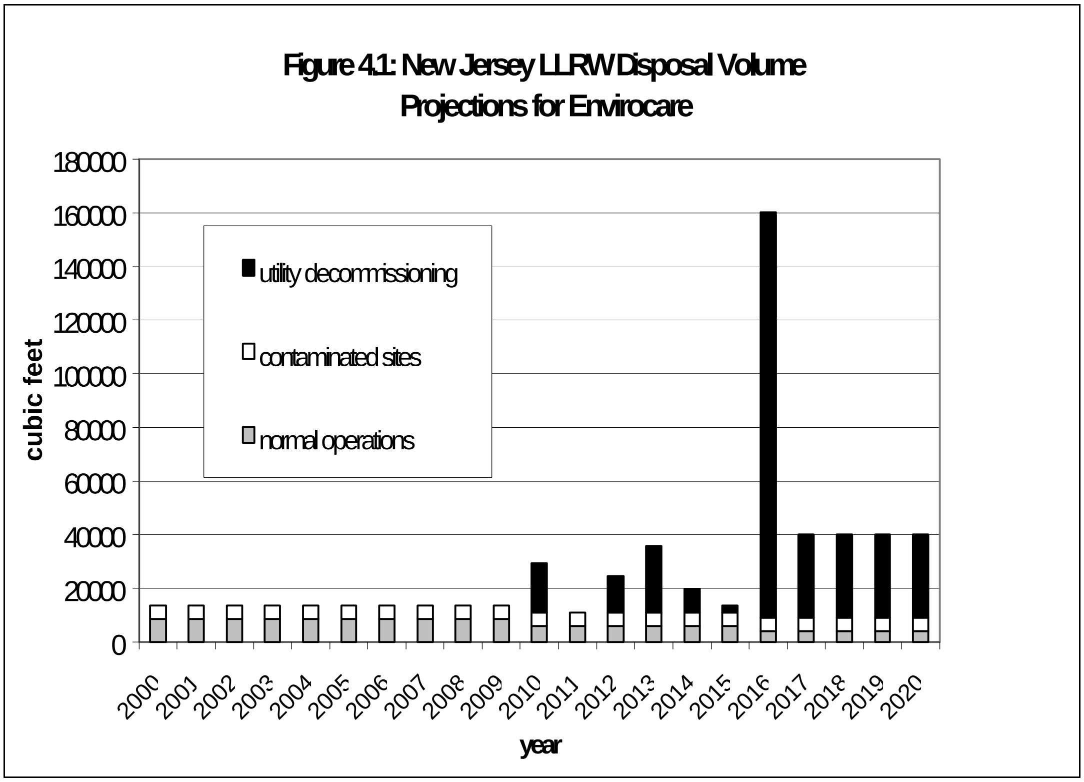
[8] March 16, 2000 email from Miranda to Truskowski, "Draft Report to the State of New Jersey, Oyster Creek Low- Level Radioactive Waste Burial Volumes"
[9] May 8, 2000 email from Russell to Truskowski, "Waste Disposal Projections" (Salem I and II and Hope Creek)



4.4 Waste Projections

Figure 4.2 shows that during the next 20 years, projected volumes for LLRW disposal at the Barnwell, South Carolina site, will be primarily governed by the projected start of D&D at Oyster Creek in 2010, at Salem I in 2016, and at Salem II in 2020.

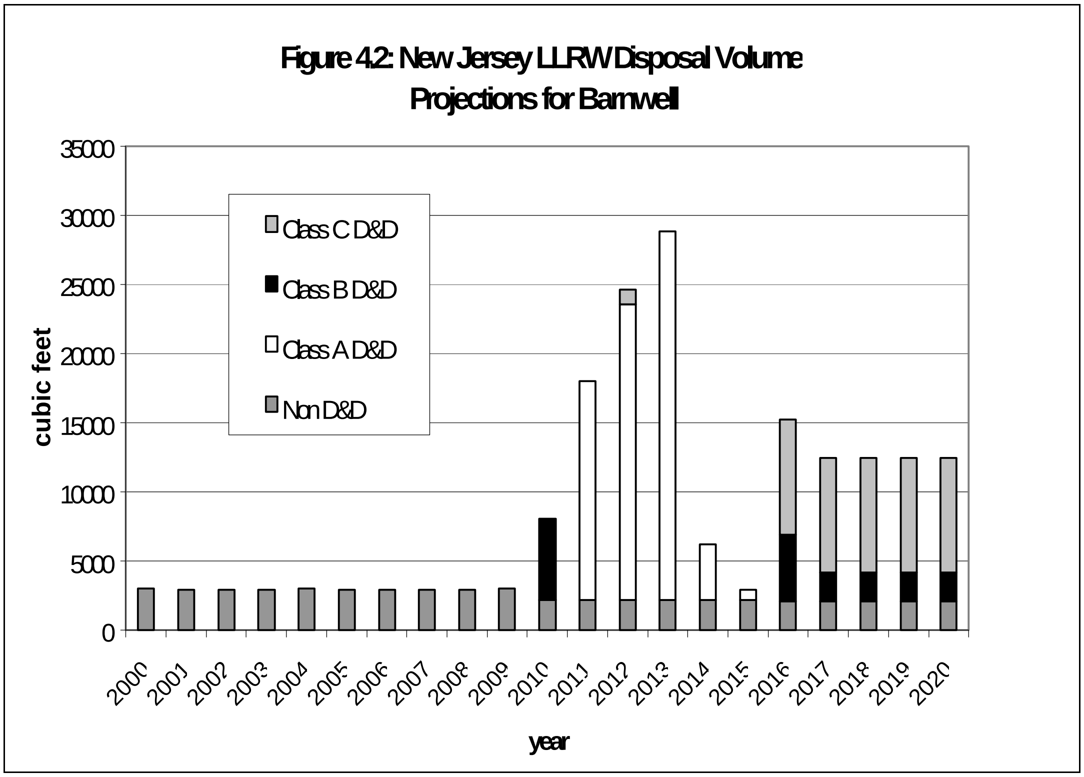
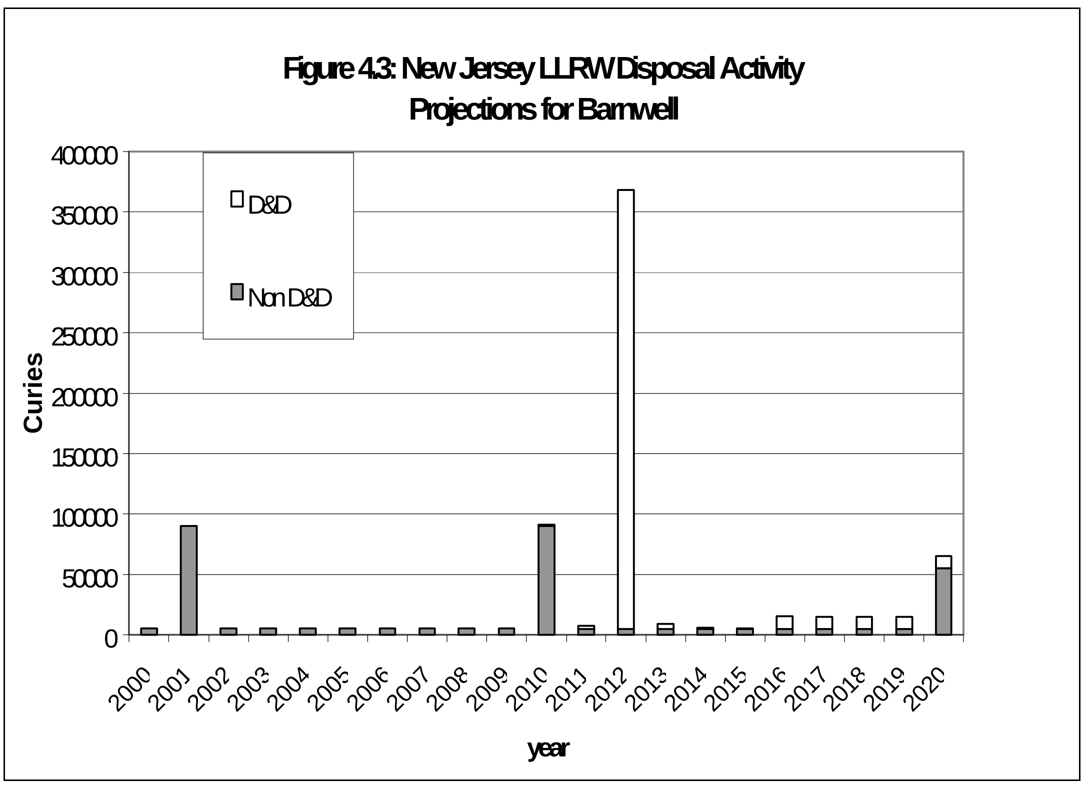


Figure 4.3 shows the projection of activity disposal in curies during the next 20 years.



4.5 Waste Management and Processing

4.5.1 Waste Minimization

Waste minimization programs have been aimed at minimizing the generation of LLRW requiring disposal. Examples of waste minimization practices include:

- optimizing practices and procedures to minimize the use of radioactive materials;
- reducing the introduction of materials into radiologically controlled areas;
- better sorting of "clean" trash from radiologically contaminated trash in dry active waste streams; and
- using protective clothing and equipment that can be laundered and/or incinerated as permitted under state and federal regulations.

Implementation of waste minimization programs often involves changing existing management practices and re-training personnel.

Storage for decay is the storage of LLRW for a sufficient period of time to allow radioactive decay to virtually eliminate the radioactivity in the waste. Storage for decay is licensed and regulated by the NRC as an alternative to disposal for wastes that contain radionuclides with relatively short half-lives (often <120 days). After being held for decay, the waste is surveyed to ensure there is no detectable residual radioactivity. The waste may then be disposed without regard to its radioactivity, but must comply with all applicable requirements for disposal as non-radioactive waste. Since waste streams held for decay under NRC regulations are no longer considered radioactive, they do not need to be sent to a LLRW disposal facility.

Some radioactive materials, such as sealed sources, can be recycled by the original manufacturer. Sealed sources are granules of radioactive material sealed inside small capsules. They are used in various commercial applications such as radiography devices and well-logging equipment as well as in medical applications. Some types of sealed sources can be reused. For example, a sealed source that has decayed significantly from its initial activity can sometimes be reused in an instrument requiring a lower radioactivity source.

Many contaminated metallic components from nuclear power plants are sent out-of-state to a processing vendor for decontamination and recovery. Other metallic wastes are also sent out-of-state to a processing vendor for "metal melt," a process that re-melts metals to manufacture shielding products. Programs are also underway to re-melt metallic components of decontamination and decommissioning (D & D) waste streams to manufacture metal containers used for LLRW disposal.

Nuclear power plants minimize liquid treatment wastes at the source of generation by the use of an on-site waste water treatment system that incorporates waste separation and thermal reduction. This system minimizes the use of process media in waste water treatment, significantly reducing the volumes of LLRW generated during liquid processing. A technology that may be used in the future involves chemical regeneration of ion exchange resins for reuse. Vendor literature indicates that reusing can reduce the volume of ion exchange resin waste by a factor of more than three, compared to single use followed by dewatering into a High Integrity Container.

With the cost per unit volume of waste disposal continuing to increase, facilities are examining many different techniques to decrease their disposal volume.

4.5.2 Processing

Processing of LLRW can be used to achieve one or more goals, including volume reduction, stabilization, removal of free liquids, and removal of non-radioactive material from the waste stream.[10] The final waste form must comply with the waste acceptance criteria for the disposal facility.

Various physical and chemical techniques can be used to reduce the volume of waste prior to interim storage or disposal. Compaction, supercompaction and incineration are used to reduce the volume of solids. Evaporation and reverse osmosis are two of the methods to reduce the volume of liquids. Supercompaction services are available to New Jersey generators at out-of-state processing vendors.

The degree of volume reduction achieved through compaction methods depends on the density of the waste and the compaction force applied. Supercompaction can typically reduce dry active waste by a factor of two to five. Volume reduction can also be achieved by incineration, which is also available at out-of-state processing vendors. The reduction of volume by incineration depends on the waste. Incineration can typically reduce dry active waste by a factor of ten to 100.

Volume reduction is not always practiced. A current disposal option is to send LLRW with low concentrations of radioactive material to the Envirocare facility in Clive, Utah. Envirocare requires that material not be compacted so that it can be mixed with clean or slightly contaminated soil or rubble. However, a high percentage of the material destined for the Chem-Nuclear facility in Barnwell, South Carolina is volume reduced because of the relatively high disposal cost.

The NRC[11] defines stable waste forms as those able to maintain gross physical properties and identity for over 300 years. Low-level radioactive waste may be stabilized by a number of immobilization methods such as solidification with cement or asphalt. Solidification serves the dual purpose of stabilizing the waste and removing free liquids. Although most solidification techniques increase volume, solidification with asphalt decreases volume.

Vitrification (superheating to form a glass matrix) not only produces a highly stable, non-leaching waste form but also provides significant volume reduction. Vendor literature indicates that incinerator ash can be reduced by a factor of three, while liquid treatment wastes (e.g., ion exchange resins) can be reduced by a factor of at least 20. Vitrification is available at out-of-state processing facilities.

Steam Reforming (also called Steam Detoxification or Thermal Decomposition) is a newly patented and available waste processing technology to treat organic LLRW such as biological waste and some liquid processing wastes. Steam Reforming reduces the volume by

[10] All Waste processing must comply with applicable NRC (or Agreement State) regulations for handling and treating LLRW.

[11] 10CFR61.7(b)(2)

converting the waste, without combustion, into an end product similar to incinerator ash. High temperature steam reformation chemistry is used to convert volatilized organics into carbon monoxide, hydrogen gas, carbon dioxide, water and methane. The organic wastes are then reduced to a small volume of inorganic residue that can be supercompacted, vitrified or incinerated to obtain further volume reduction. This technology is especially helpful to small generators, since drums are processed individually without commingling isotopes from other batches. Vendor literature indicates that this technology may be applied to ion exchange resins to obtain a volume reduction factor of about six.

Another new waste processing technology that is applied to resins is Catalytic Extraction Processing (CEP). A bath of molten metal (3,500°F) is used to destroy the organic components of resin and control the partitioning of radionuclides into three physical phases: gas, ceramic matrix and metal. Volume reduction is achieved because all water in the resin is converted to hydrogen, oxygen and water vapor. Metallic radionuclides are captured in the solid metal waste form, which exhibits excellent stability and shielding characteristics.

4.5.3 Waste Disposal Alternatives Allowed Under 10CFR20

The NRC allows several alternatives to land disposal. Many generators use these disposal alternatives to minimize the amount of LLRW requiring disposal in a LLRW disposal facility. Facilities that dispose of LLRW using any of these alternatives to land disposal must maintain records of such disposal.[12]

- Certain LLRW may be disposed of by release into a sanitary sewer system.[13] Material to be disposed of by release into sanitary sewers must be readily soluble in water, or it must be biological material that is dispersible in water. Additionally, the effluent discharged into the sewer must meet average monthly concentration limits as well as annual total radioactivity limits: 5 curies of tritium, 1 curie of carbon-14, and 1 curie of all others combined. To comply with specific licensing restrictions, actual releases are usually much less than the regulatory limits.
- Liquid scintillation fluid and animal tissue, if it contains only very low concentrations (0.05 microcuries[14] per gram) of tritium or carbon-14, may be disposed of (e.g., by incineration) as if it were not radioactive.[15] Many facilities dispose of liquid scintillation fluid by sending it to an out-of-state liquid incineration facility. Animal tissue must still meet regulations pertaining to biomedical waste, even if it is disposed of without regard to its radioactivity.
- Generators may also obtain permission to incinerate waste types other than liquid scintillation fluid and animal tissue, such as dry active waste. In order to obtain a NRC license amendment for any proposed disposal procedure such as incineration of dry active waste, a facility must demonstrate that doses will be maintained as low as reasonably achievable (ALARA) and within the dose limits for all effluent releases specified in 10 CFR 20.1301.[16]

Nuclear power plants do not use these disposal alternatives; they are subject to additional restrictions contained in 10 CFR 50.36a. Records of effluent releases by nuclear power plants are filed semi-annually with the NRC. All NRC licensed facilities must maintain records

[12] 10CFR20.2108
[13] 10CFR20.2003
[14] A microcurie is equal to one-millionth of a curie.
[15] 10CFR20.2004-2005
[16] 10CFR20.2002

sufficient to demonstrate that potential doses from operations, including effluent releases, are kept within the dose limits specified in 10 CFR 20.1301.[17]

5.0 LLRW Disposal Methods

5.1 Existing Disposal Options

Since South Carolina's Barnwell facility will be available to New Jersey generators over the next 50 years, the Siting Board is not considering siting a disposal facility in New Jersey at this time. Consequently, there are no disposal methods under consideration. Methods that were previously considered can be found on pages 49-55 in the *1996 Update* of the Disposal Plan.

5.2 Projected Disposal and Storage Options

The disposal facility in Barnwell, South Carolina uses below grade concrete modules for disposal. Envirocare of Utah disposes of the allowable low concentration material in earthen mounds.

A number of states have considered building an assured isolation facility to manage their LLRW. This type of facility is designed to store the waste so that the option to retrieve it in the future remains viable. In contrast, disposal facilities are designed with limited options for retrieval.

Consistent with the Board's 1999 Disposal Options Report to the Governor of New Jersey, the Siting Board worked with the Northeast Compact Commission and the State of Connecticut in negotiations that concluded with the State of South Carolina joining the Northeast Compact (now called the Atlantic Compact). This development provides both New Jersey and Connecticut with long term commitment for access to a low-level radioactive waste disposal facility at the existing Barnwell, South Carolina site and meets the South Carolina desire to limit future disposal activities at that site.

6.0 LLRW Transportation

6.1 Regulatory Framework

Most commercial low-level radioactive waste contains small amounts of radioactivity. Solid low-level radioactive waste is usually compacted into steel boxes or drums for disposal. Liquid, pyrophoric or explosive wastes are not accepted at disposal sites. Materials that contain higher amounts of radioactivity are shipped in containers that have undergone stringent testing and meet federal requirements to withstand accident conditions.

The transportation of low-level radioactive waste is subject primarily to federal regulation by the U.S. Department of Transportation (DOT) under the Hazardous Materials Transportation Act[18](HMTA), and the U.S. Nuclear Regulatory Commission (NRC) under the Atomic Energy

[17] 10CFR20.2107
[18] 49 U.S.C. 1801 et. seq.

Act[19](AEA) and the Energy Reorganization Act.[20] The HMTA authorizes DOT to promulgate a comprehensive set of regulations for the safe transport of hazardous materials, including radioactive materials, in commerce. The HMTA expressly preempts inconsistent state and local laws. DOT's hazardous materials transportation regulations are contained in 49 CFR Parts 171-177. The AEA authorizes the NRC to regulate and license the receipt, possession, use and transfer (including transportation) of source, by-product and special nuclear material. The NRC's radioactive materials transportation regulations are contained in 10 CFR Part 71.

The DOT and NRC enforce regulations that control the types of shipping containers and packaging used in radioactive waste shipments. Low-level radioactive waste must be packaged to ensure minimal radiation exposure to workers and the public, which is accomplished by proper shielding and packaging to minimize breakage and leakage. Packages and shipments must be labeled, and placards must be placed on the transport vehicles to specifically identify the contents and any radiation exposure from the packages.[21]

6.2 Existing Transportation System

During the period 1994-1998, low-level radioactive waste was transported directly from the generators or through brokers to waste disposal sites in Barnwell, South Carolina and Clive, Utah or to waste processors out-of-state. For one year, beginning July 1, 1994, New Jersey generators stored the low-level radioactive waste they generated. This was because Barnwell was closed to all states outside of the Southeast Compact. The South Carolina State Legislature voted to reopen Barnwell to accept waste from other states as of July 1, 1995.

Shipments originating from the four power plants destined for a disposal facility or a processor took the most direct routes to the Delaware River bridges and out of New Jersey.

Low-level radioactive waste not generated by the nuclear power plants is typically collected by waste brokers located principally in a metropolitan area. Waste is collected from a number of generators, consolidated into a shipment and transported out of New Jersey via interstate routes such as the New Jersey Turnpike or I-80. The major brokers used by New Jersey generators include Chem-Nuclear, NDL, Radiac, Teledyne and U.S. Ecology.

6.3 Transportation Costs

Transportation costs associated with hauling low-level radioactive waste are calculated primarily on the basis of a per-mile hauling charge to the shipper and an additional daily fee for shielding cask rental, if required. (The purpose of the cask is to provide radiation shielding for higher activity low-level radioactive waste.) The hauling charge is subject to negotiation between the shipper and truck carrier, and the cask rental fee is negotiable with the cask vendor.

Given the current cost of low-level radioactive waste disposal, the cost of transporting waste is relatively minor. For example, in 1999, the cost for transporting New Jersey low-level

[19] 42 U.S.C. 2011 et seq.
[20] 42 U.S.C. 5901 et seq.
[21] Low-specific activity (LSA) material transported on an exclusive use vehicle are exempt from these requirements as per 49 CFR 173.425.

radioactive waste to Barnwell was approximately $5 per cubic foot. Correspondingly, the disposal fees and surcharges paid to the South Carolina average over $500 per cubic foot.

7.0 Commercial Viability of a New Jersey Facility

It is apparent that the disposal management of low-level radioactive waste throughout the nation is in a state of flux. However, the current private low-level radioactive waste disposal vendors believe that the situation will be stabilized within the next five years through their companies' efforts and/or by a change in the federal *Low Level Radioactive Waste Policy Act*. These firms also believe that the reduced volume of commercial low-level radioactive waste can be accommodated in existing and proposed privately operated disposal sites.

Initially, the New Jersey Low-Level Radioactive Waste Disposal Facility Siting Board suspended in-state siting efforts in response to these national conditions and the fact that currently there were disposal facilities available to New Jersey generators of radioactive waste. However, now that South Carolina is a member of the Atlantic Compact with New Jersey and Connecticut, New Jersey generators have access to a disposal site for the next 50 years at Barnwell, South Carolina.

Appendix A

Facilities in New Jersey which used the Barnwell facility from 1994-1998

(facilities marked with an * do not have NRC licenses)

Category: **academic**

Facility Name	City
BLOOMFIELD COLLEGE*	BLOOMFIELD
CAMDEN BOARD OF EDUCATION*	CAMDEN
CHERRY HILL BOARD OF EDUCATION*	CHERRY HILL
CHRISTIAN BROTHERS ACADEMY*	LINCROFT
COUNTY COLLEGE OF MORRIS	RANDOLPH
EWING BOARD OF EDUCATION*	EWING
MONMOUTH COLLEGE*	WEST LONG BRANCH
NEW JERSEY CITY UNIVERSITY*	JERSEY CITY
PRINCETON UNIVERSITY	PRINCETON
RICHARD STOCKTON COLLEGE OF NJ, THE	POMONA
RUTGERS, THE STATE UNIVERSITY	PISCATAWAY
SETON HALL UNIVERSITY	SOUTH ORANGE
STEVENS INSTITUTE OF TECHNOLOGY	HOBOKEN
THE COLLEGE OF NEW JERSEY	EWING
UMDNJ, MEDICAL SCHOOL	NEWARK
UMDNJ, SCHOOL OF OSTEOPATHIC MED.	STRATFORD
UNION COUNTY COLLEGE*	CRANFORD
WILLIAM PATERSON COLLEGE	WAYNE

Category: **government**

Facility Name	City
DEP - BUREAU OF EMERGENCY RESPONSE*	TRENTON
DEPT. OF VETERANS AFFAIRS	EAST ORANGE
FEDERAL BUREAU OF PRISONS*	FAIRTON
MONMOUTH COUNTY DOH*	FREEHOLD
MONTGOMERY TOWNSHIP*	MONTGOMERY
NJ DEPT. OF HUMAN SERVICES*	TRENTON
NJSTATE POLICE	PRINCETON
NJ DEPT. OF ENVIRONMENTAL PROTECTION	TRENTON
US ARMY	PICATINNY ARSENAL
US ARMY	FORT MONMOUTH
US ENVIRONMENTAL PROTECTION AGENCY*	EDISON

Category: **industrial**

Facility Name	City
62-68 COLFAX CORP.*	LAKEWOOD, NJ
680 GARFIELD AVE., INC.	JERSEY CITY
ACCREDITED LABORATORIES, INC.	CARTERET
AEROCHEM RESEARCH LABS*	PRINCETON
AIRTRON DIV., LITTON SYSTEMS, INC.*	MORRIS PLAINS
ALLIANT TECHSYSTEMS INC.	TOTOWA
ALLIED-SIGNAL INC.	MORRISTOWN
ALTEON, INC.	RAMSEY

AMERICAN CYANAMID COMPANY	PRINCETON
AMERICAN HOME PRODUCTS*	MADISON
AMERSHAM/MEDI-PHYSICS, INC.	SOUTH PLAINFIELD
APOLLO ASSOCIATES*	WHIPPANY
AT&T*	CLARK
ATLANTIC EQUIPMENT ENGINEERING*	BERGENFIELD
BECTON DICKINSON LABWARE	FRANKLIN LAKES
BELL LABORATORIES	MURRAY HILL
BERLEX LABORATORIES, INC.	WAYNE
BIO-REFERENCE LABORATORIES, INC.	ELMWOOD PARK
BIOMATRIX, INC.	RIDGEFIELD
BLOCK DRUG CO., INC.	JERSEY CITY
BOC GROUP, INC. (THE)	MURRAY HILL
BRACCO RESEARCH USA INC.	PRINCETON
BRISTOL-MYERS SQUIBB	NEW BRUNSWICK
BRUSH WELLMAN*	FAIRFIELD
C&S CLINICAL LABORATORY INC.	ENGLEWOOD
CAMPBELL SOUP COMPANY	CAMDEN
CARTER-WALLACE, INC.	CRANBURY
CELGENE CORPORATION	WARREN
CHASE PHARMACEUTICAL*	PARSIPPANY
CHASE PHARMACEUTICAL*	NEWARK
CITY CHEMICAL CORP.*	JERSEY CITY
CLAYTON ENVIRONMENTAL CONSULTANTS	EDISON
CLINICAL PATHOLOGY LABORATORY*	BLOOMFIELD
COLGATE PALMOLIVE CO.	PISCATAWAY
E&G PLASTICS*	PISCATAWAY
EASTERN HIGH VOLTAGE, INC.	ROBBINSVILLE
EDAX, INC.	MAHWAH
EG & G INSTRUMENTS*	OAK RIDGE
ELKINS-SINN, DIV. OF A.H. ROBINS CO*	CHERRY HILL
ENGELHARD RESEARCH AND DEVELOPMENT	ISELIN
ENVIROGEN, INC.	LAWRENCEVILLE
ETHICON, INC.	SOMMERVILLE
EXXON RESEARCH & ENGINEERING CO.	ANNANDALE
FISHER SCIENTIFIC COMPANY	FAIR LAWN
FLEXON INDUSTRIES*	NEWARK
FLUID PACKAGING*	TOMS RIVER
FMC CORPORATION	PRINCETON
FOREMAN STERN*	PARAMUS
FRENCHTOWN CERAMICS*	FRENCHTOWN
GENERAL FOODS CORP.	HOBOKEN
GUS ANDY*	CAPE MAY
HATCO CORPORATION*	FORD
HIGHVIEW ASSOCIATES*	EAST BRUNSWICK
HOECHST MARION ROUSSEL, INC	BRIDGEWATER
HOFFMANN-LA ROCHE, INC.	NUTLEY
HOWMET DOVER CASTING	DOVER
IMMUNOBIOLOGY RESEARCH INSTITUTE	ANNANDALE

INTERCARDIA RESEARCH LABS	CRANBURY
INTERFERON SCIENCES, INC.	NEW BRUNSWICK
INTERNATIONAL FRAVORS AND FRAGRANCE*	UNION BEACH
J. T. BAKER, INC.	PHILLIPSBURG
JOANN ELHALIN*	UNION
JOHNSON & JOHNSON CONSUMER PRODUCTS	NORTH BRUNSWICK
JOHNSON & JOHNSON CONSUMER PRODUCTS	SKILLMAN
KABI PHARMACIA, INC.	PISCATAWAY
KEARFOTT GUIDANCE & NAVIGATION	WAYNE
KOEHLER BRIGHT STAR*	CLIFTON
KOOLTRONICS*	HOPEWELL
L-3 COMMUNICATIONS SYSTEMS - EAST	CAMDEN
LEDOUX & COMPANY	TEANECK
LFR (Levine Fricke Recon)	RARITAN
LIPOSOME COMPANY INC. (THE)	PRINCETON
LOCKHEED MARTIN, GOV. ELECTRONIC SY	MOORESTOWN
LONZA INC.*	ANNANDALE
MALLINCKRODT/BAKER*	PHILLIPSBURG
MERCK & CO., INC.	RAHWAY
MOBIL CHEMICAL COMPANY	EDISON
MOBIL TECHNICAL CENTER	PRINCETON
NABISCO BRANDS, INC.	EAST HANOVER
NATIONAL STARCH & CHEMICAL*	BRIDGEWATER
NITTA CASINGS*	SOMERVILLE
NORTH ATLANTIC PROPERTIES*	MAHWAH
NOVARTIS PHARMACEUTICAL CORP.	EAST HANOVER
NOVARTIS PHARMACEUTICAL CORP.	SUMMIT
PF LABS*	TOTOWA
PHARMACOPEIA, INC.	PRINCETON
PHARMAGENICS, INC.	ALLENDALE
PHILIPS LIGHTING CO.	SOMERSET
PRINCETON GAMMA-TECH, INC.	ROCKY HILL
QUEST DIAGNOSTICS	TETERBORO
R.W.JOHNSON PHARMACEUTICAL RESEARCH	RARITAN
RESEARCH COTRELL*	BRIDGEWATER
REVLON RES. CTR.	EDISON
RHEOX*	HIGHTSTOWN
RHODIA, Inc*	CRANBURY
RHONE-POULENC, INC.	DAYTON
RONSON METALS CORP.	SOMERSET
ROSEMONT ANALYTICAL*	CEDAR GROVE
SCHERING CORPORATION	KENILWORTH
SCHLUMBERGER EMR	PRINCETON JUNCTION
SHARP ELECTRONICS CORP.	MAHWAH
SHULLER INTERNATIONAL*	BERLIN
SMITH KLINE BEECHAM*	CLIFTON
SMITH KLINE BEECHAM*	PARSIPPANY
SYNAPTIC PHARMACEUTICAL CORPORATION	PARAMUS

TELECORDIA TECHNOLOGIES (BELLCORE)	PISCATAWAY
TELEDYNE ENVIRONMENTAL INC.	WESTWOOD
TEVA, USA*	WALDWICK
THIN FILM INC.*	EAST BRUNSWICK
TICONA LLC	SUMMIT
TRANSCONTINENTAL*	LINDEN
UNIGENE LABORATORIES, INC.	FAIRFIELD
UNILEVER RESEARCH U.S., INC.	EDGEWATER
UNION CARBIDE CORPORATION	BOUND BROOK
WARNER-LAMBERT COMPANY	MORRIS PLAINS
WATERS, MCPHERSON, MCNEIL*	
WIEN LABORATORIES, INC.	FLANDERS
WYETH-AYERST RESEARCH	MONMOUTH JUNCTION
XENOBIOTIC LABS., INC.	PLAINSBORO
ZENITH GOLDLINE PHARMACEUTICAL*	NORTHVALE

Category: **medical**

Facility Name	City
COLUMBUS HOSPITAL	NEWARK
DEBORAH RESEARCH INSTITUTE	BROWNS MILLS
GARDEN STATE CANCER CENTER	BELLEVILLE
MEDICAL CENTER AT PRINCETON (THE)	PRINCETON
NEWARK BETH ISRAEL MEDICAL CTR.	NEWARK
RADIOLOGY-ULTRASOUND-NUCLEAR CONSUL	FREEHOLD
ROBERT WOOD JOHNSON-UNIV. HOSPITAL	NEW BRUNSWICK
ST. CLARE'S HOSPITAL	DOVER
ST. PETER'S MEDICAL CENTER	NEW BRUNSWICK
UNITED HEALTHCARE SYSTEM	NEWARK

Category: **utility**

Facility Name	City
GPU NUCLEAR CORP.	FORKED RIVER
PSE&G HOPE CREEK NUC. GEN. STATION	HANCOCKS BRIDGE
PSE&G SALEM NUC. GEN. STATION	HANCOCKS BRIDGE

Appendix B

Annual Average Curies Disposed in 1994-1998 and Curie Quantity After 100 Years of Decay

Radionuclide	Average Curies	Half Life [years]	Curies in 100 years
Ac-227	0.00	21.6000	0.00
Ag-110m	1.49	0.6986	0.00
Am-241	0.01	458.0000	0.01
As-73	0.00	0.2200	0.00
Ba-133	0.01	7.2000	0.00
Bi-207	0.00	30.2000	0.00
Bi-210	0.00	0.0137	0.00
C-14	5.01	5,730.0000	4.95
Ca-45	0.00	0.4521	0.00
Cd-109	1.62	1.2411	0.00
Ce-139	0.00	0.3836	0.00
Ce-141	0.02	0.0890	0.00
Ce-144	1.19	0.7781	0.00
Cf-252	0.00	2.6460	0.00
Cl-36	0.00	308,000.0000	0.00
Cm-242	0.01	0.4452	0.00
Cm-243	0.01	32.0000	0.00
Cm-244	0.00	17.6000	0.00
Co-57	0.14	0.7397	0.00
Co-58	4.77	0.1953	0.00
Co-60	1120.73	5.2630	0.00
Cr-51	13.68	0.0762	0.00
Cs-134	8.10	2.0460	0.00
Cs-137	60.50	30.0000	6.01
Fe-55	3342.86	2.6000	0.00
Fe-59	4.14	0.1249	0.00
Gd-148	0.00	84.0000	0.00
Gd-153	0.00	0.6630	0.00
H-3	56.95	12.3000	0.20
Hg-203	0.00	0.1285	0.00
I-125	0.09	0.1649	0.00
I-129	0.00	17,000,000.0000	0.00
I-131	0.01	0.0221	0.00
K-40	0.01	1,260,000,000.0000	0.01
Kr-85	0.03	10.7600	0.00
Mn-54	297.27	0.8301	0.00
Na-22	0.00	2.6200	0.00
Nb-95	0.02	0.0959	0.00
Ni-59	0.22	80,000.0000	0.22
Ni-63	116.07	92.0000	54.65
Np-237	0.00	2,140,000.0000	0.00
P-32	0.02	0.0391	0.00
P-33	0.01	0.0668	0.00
Pa-233	0.01	0.0740	0.00

Pb-210	0.00	20.4000	0.00
Pm-147	0.02	2.6200	0.00
Po-210	0.00	0.3792	0.00
Pu-238	0.01	86.4000	0.01
Pu-239	0.01	24,390.0000	0.01
Pu-241	0.26	13.2000	0.00
Pu-244	0.00	76,000,000.0000	0.00
Ra-226	0.01	1,602.0000	0.01
S-35	0.03	0.2408	0.00
Sb-124	0.01	0.1655	0.00
Sb-125	0.85	2.7100	0.00
Sc-46	0.00	0.2299	0.00
Sm-145	0.00	0.9315	0.00
Sn-113	0.00	0.3151	0.00
Sr-85	0.00	0.1753	0.00
Sr-89	0.72	0.1444	0.00
Sr-90	0.46	27.7000	0.04
Tc-99	0.02	212,000.0000	0.02
Te-123	0.00	12,000,000,000,000.0000	0.00
Th-228	0.00	1.9100	0.00
Th-230	0.00	80,000.0000	0.00
Th-232	0.01	14,100,000,000.0000	0.01
Th-234	0.00	0.0660	0.00
Tl-204	0.00	3.8100	0.00
U-235	0.00	710,000,000.0000	0.00
U-238	0.01	4,510,000,000.0000	0.01
Y-88	0.00	0.2962	0.00
Zn-65	308.75	0.6712	0.00